PHYSIOGRAPHIC PROBLEMS OF TODAY.[1]

In looking ahead and endeavoring to see in what ways our knowledge of the earth's surface can be increased, the fact should be borne in mind that physiography is one of the younger of the sciences. In truth, the new geography, or physiography as it has been christened, is of such recent birth that its limits and its relationship to other sciences are as yet in part, indefinite. Accepting the conservative view, that physiographers should confine their studies to the earth's surface, but have freedom to investigate the causes producing changes of that surface, whether coming from without or arising from forces at work within the earth, my task is to suggest ways in which man's knowledge of his dwelling-place may be enlarged.

INHERITANCES.

Although the scientific study of the earth's surface can with sufficient accuracy be said to be less than a century old, and to have attained the greater part of its growth during the past half-century, the fact must be freely admitted that, preceding the recognition of physiography as one of the sisterhood of sciences, there was a long period of preparation during which man's physical environment, and the many changes to which it is subject, attracted attention and awakened interest. The more or less general and diffuse descriptions of the earth's surface embraced under the term "physical geography," when vivified by the idea of evolution, became the more definite and concrete physiography of today. Physiography from this point of view may perhaps be justly designated as scientific physical geography. New thoughts grafted on the previously vigorous stem have borne rich fruits, but in many instances inherit much of their flavor from the original trunk. One of the important duties of the physiographer is to select all that is of value from the inheritance that has come to him, whether of fact, or theory, or suggestion and give it a place in his systematically classified records.

[1] Read before the section of Physiography, International Congress of Arts and Science, Universal Exposition, St. Louis, September 21, 1904.

In the physical geographies on our library shelves, in books of travel, in transactions of learned societies, etc., pertaining to the era preceding the time when physical geography became a science, there are numerous records of facts, concealed perhaps in part in dreary cosmogonies and exuberant theories, which in many instances are of exceptional value because, in part, of the date at which they were observed. One of the leading ideas in scientific geographical study is the recognition of the wide-reaching principle that changes are everywhere in progress. Many, if not all, of the changes referred to have an orderly sequence, and constitute what may be suggestively termed life-histories. In writing the biographies of various features of the earth's surface the observations made a century, or many centuries, ago have a peculiar, and in some instances an almost priceless, value, because of the light they furnish as to the sequence of events. In this and yet other ways the records left by past generations of geographical explorers contain valuable legacies. In attempting to winnow the wheat from the chaff of physical geography, the physiographer should avoid the conceit of youth, and fully recognize the work of the bold and hardy pioneers who blazed the way for the more critical and better-equipped investigators who came later.

NOMENCLATURE.

One of the reasons for the slow growth of knowledge concerning the earth's surface during the centuries that have passed was the fact that the objects which claimed attention were, to a great extent, designated by terms derived from popular usage. The language of geography, in large part of remote antiquity, was adopted from the parlance of sailors, hunters, and others in the humbler walks of life, and retained its original looseness of meaning. The change from geographical description to scientific analysis, which marked the birth of physiography, necessitated greater precision in the use of words. This change is not yet complete, and physiography is still hampered in its growth and usefulness by a lack of concrete terms in which tersely and accurately to state its results. In the nomenclature of physiography today the words inherited from physical geography by far outnumber the technical terms since introduced, and to a large extent still retain the indefiniteness and lack of precision that charac-

erize the multiple sources from which they were adopted. One of the pressing duties of the scientific student of the earth's surface, and one which on account of its many difficulties may well be reckoned among the physiographic problems of today, is the giving of fixed and precise meanings to the words employed in describing and classifying the features of the earth's surface A scientific physiographical nomenclature is of importance, not only to the special students of the earth's surface, but through them to communities and patrons. The diverse interpretations that have been given to such seemingly simple terms as "shore," "lake," "river," "hill," "mountain," "divide," etc., as is well known, have led to misunderstandings, litigations, international disputes, and even threatened to bring on war between highly civilized nations. A duty which physiographers owe, not only to their science in order that its continued advancement may be assured, but to communities in payment for the terms borrowed from them, as well as for the general good, is a systematic effort accurately to define the words and terms now used to designate the features of the earth's surface. Careful attention needs to be given also to the coinage of new terms when their need is definitely assured. An appropriate task for a group of physiographers would be the preparation of a descriptive geographical dictionary, suited to the wants of both the specialist and the layman.

While considering the advantages of a language of science, its disadvantages should also be recognized.

The histories of all sciences show that, as they became more and more precise, and as their nomenclature grew so as to meet their internal requirements more and more completely, they at the same time, on account of the very precision and accuracy of their language, became more and more circumscribed and farther and farther removed from the great mass of humanity for whose use and benefit they exist. Not only this, but a science dealing with facts of vast public importance and filled with instructive and entertaining matter — nay, in itself even poetic and as fascinating as the pages of a story-book—has, in not a few instances, been rendered difficult to understand, and even repellant to the general reader, by a bristling array of esoteric terms built about it like an abatis.

Between the two extremes—on the one hand, a science without

words in which to speak concisely and accurately, the condition in which the physiographer finds himself at the present time; and, on the other hand, a science with a language so technical and abstruse that it seems a foreign tongue to the uninitiated—is there not a happy mean? Such a much-to-be-desired end seems to be within the grasp of the physiographer. By giving precision to, and defining the bounds of words inherited from physical geography, and adding to the list such terms as are strictly essential in the interest of economy of time and space, or for accuracy—such contributions, so far as practicable, to be chosen from the language of everyday life—it would seem as if a nomenclature could be formulated which would at the same time meet the requirements of the scientific student and enable the general reader of average intelligence to receive instruction and inspiration from the talks and writings of the especially qualified interpreters of nature.

EXPLORATION.

Physiography, to a great extent, is still in the descriptive stage of its development, but the descriptions demanded are such as discriminate and select the essential, or suggestive, from the confusing wealth of secondary details frequently present. The records should also include comparisons between the objects described and analagous topographic or other physiographic features, and, within safe and reasonable limits, be accompanied by explanations of their origin and life-histories.

One of the important functions of physiography, as a more mature growth of physical geography, is to continue and render more complete the exploration of the earth's surface and to conduct resurveys where necessary. Geographical exploration has, as is well known, been carried on viogrously, although spasmodically, in the past, and the areas marked "unknown" on our globes have become smaller and smaller, and more and more isolated. The more critical physiographic studies, however, which have for their object not only the description of coast lines, mountain ranges, plains, etc., but a search for the records of their birth, the discovery of their mode of development and their assignment to a definite place in the complex whole, termed man's environment, has progressed but slowly. In this stricter sense, the unknown areas on the earth's surface embrace regions of continental

extent. It is this latter method of geographical exploration and survey which now demands chief attention.

The terms "exploration" and "survey" are here used advisedly, as two divisions of physiographic field-work may justly be recognized. These are: first, travel in which physiographic observations are incidental to other aims, or perhaps the leading purpose in view, as during a physiographic reconnaissance; and, second, detailed surveys and critical study of definite areas or of concrete problems. Each of these subdivisions of the great task of making known the beauties and harmonies of man's dwelling-place has its special functions.

From the observant traveler we expect comprehensive and graphic descriptions of the regions visited, rendered terse by the use of well-chosen terms, in which the more conspicuous elements of relief, and other physiographic features, and their relation to life, shall be clearly and forcibly presented. In order to render this service, the traveler should not only be familiar with the broader conclusions and fundamental principles of physiography, but skilled in the use of its nomenclature. The chief contribution to the science of the earth's surface demanded of the explorer of new lands is a careful record of facts. When a journey becomes a reconnaissance with physiography as its leading feature, it is not only an advance into a more or less unknown region, but an excursion into the realm of ideas as well. It is during such explorations, when one's mind is stimulated by new impressions, that hypotheses spring into existence with greatest exuberance. While most of these springtime growths are doomed to wither in the more intense heat of subsequent discussion, their spontaneity, and the fact that the mind when not oppressed by a multitude of details grasps significant facts almost by intuition, make the suggestions of the explorer of peculiar value.

The detailed work of physiographic surveys falls into two groups: namely, the study of definite areas, and the investigation of specific problems. In each of these related methods the desirability of recording facts by graphic methods is apparent. The demand for accurate maps as an aid to both areal physiography and the study of groups of specific forms, or the functions of concrete processes, needs no more than a word at this time. With the growth of physiography the time has come when the work of the individual explorer, who from force of

circumstances endeavors to follow many of the paths he finds leading into the unknown, is replaced to a large extent by well-organized and well-equipped scientific expeditions. It is to such systematically planned campaigns, in which the physiographer and representatives of other sciences mutually aid each other, that the greatest additions to man's knowledge of the earth's surface are to be expected. The most extensive of the unexplored or but little-known portions of the surface of the lithosphere, in which a rich harvest awaits the properly equipped expedition, are the sea-floor and the north and south polar regions. As is well known, splendid advances have been made in each of these fields, but, as seems evident, much more remains to be accomplished.

In the branch of physiography appropriately termed "oceanography" the problems in view are the contour of the sea-floor, or its mountains and deeps, plains and plateaus, the manner in which each inequality of surface came into existence, and the various ways it is being modified. In both of these directions the interests of the physiographer merge with those of the biologist and the geologist. One phase of the study of the ocean's floor which demands recognition is that the topographic forms there present are such as have been produced almost entirely by constructional and diastrophic agencies, free from complications due to erosion which so frequently obscure the result of like agencies on the land. For an answer to the question: What would have been the topography of land areas, had there been no subaërial decay and denudation? the topography of submarine regions furnishes at least a partial answer. The sounding line in the Caribbean region has furnished examples of topography due, as it seems, mainly to differential movements of blocks of the earth's crust bounded by faults, which have not been modified by subaërial denudation. In a similar way, as is to be expected, a survey of other portions of the at present water-covered surface of the lithosphere will supplement our knowledge of the emerged portions of the same rock-envelope, and assist in an important way in the deciphering of their histories.

In the Arctic and Antarctic regions, where all is unknown, systematic research may be expected not only to extend many branches of physiographic study, but to bring to the front as yet unsuspected problems.

The larger of the unexplored regions of the earth, however, are not

the only portions of our field of study that demand attention. New ideas, new principles, and fresh hypotheses make an unknown country of the most familiar landscape. The definite formulation of the base-level idea, the suggestive and far-reaching principle embraced in the term "geographic cycle," the planetesimal hypothesis as to the origin of the earth, etc., furnish new and commanding points of view, or, as they may be termed, primary stations in the physiographic survey of the earth's surface by means of which previous local surveys may be correlated and corrected.

In the search for problems, the unraveling of which may be expected to advance the scientific study of the earth's surface, the writings of travelers, the pregnant suggestions of those who make reconnaissances into the realm of unknown facts and of unrecognized ideas, as well as the precise and accurate pictures of portions of the earth's surface presented on the maps of the topographer and the charts of the oceanographer, point the way to still greater advancements, and furnish inspiration to those who follow.

FUNDAMENTAL CONCEPTS.

While physiography deals with the surface features of the earth, the fact that in those features is expressed to a great extent the effects of movements originating deep within the earth, leads the student of continents and oceans to ask of the geologist and the physicist puzzling questions as to the changes that are taking place in the great central mass of our planet, and even in reference to the origin of the earth itself. So intimately are the various threads of nature-study interwoven that the full significance of many of the surface features of the earth cannot be grasped and their genesis explained until the nature and mode of action of the forces within the earth which produce surface changes are understood.

The growth of physiography up to the present time has been largely influenced by the far-reaching ideas of Laplace and others in reference to the nebular origin of the solar system. In all of the questions respecting secular changes of land areas in reference to the surface level of the ocean, the origin of corrugated and of block mountains, the fundamental nature of volcanoes, etc., the controlling idea has been that the earth has cooled from a state of fusion, and is

still shrinking on account of the dissipation into space of its internal heat.

With the recent presentation of the planetesimal hypothesis by Professor Chamberlin, a radically different point of view is furnished from which to study the internal condition of the earth. The new hypothesis—which has for its main thesis the building of a planet by the gathering together of cold, rigid, meteoric bodies, and the compression and consequent heating of the growing globe by reason of gravitational contraction—is suggestive, and seems so well grounded on facts and demonstrated physical and chemical laws that it bids fair not only to revolutionize geology, but to necessitate profound changes in methods of study respecting the larger features of the earth's surface. One of the several considerations which make the planetesimal hypothesis appeal forcibly to the inquiring mind is that it employs an agency now in operation, namely, the process of earth-growth through the incoming of meteoric bodies from space; and for this reason is welcomed by uniformitarians, since it is in harmony with their understanding of a fundamental law of nature.

In many, if not all, questions respecting the origin of the atmosphere, the ocean, continents, mountains and volcanoes, and the secular, and to a marked extent in certain instances, the daily changes they experience, it is evident that the planetesimal hypothesis necessitates a revision, or at least a review, of some of the fundamental conceptions held by physiographers. The objection will perhaps be advanced that to make such a radical change of front on the basis of a young and as yet untried hypothesis is not wise. The reply is that the older hypothesis has been tried and to a marked extent found wanting, and that the new conception of the mode of origin of the earth demands consideration, not only as affecting a large group of basement principles of interest to the physiographer, but with the view of testing the planetesimal hypothesis itself by physiographic standards.

The problems interlocked with the mode of origin of the earth, in which the physiographer shares an interest with the geologist, are the rate at which the earth's mass is now being increased owing to the ingathering of planetesimal, and the chemical and physical and perhaps life conditions of the incoming bodies; the temperature of the earth's interior, and the surface changes to be expected from its

increase or diminution; the results of gravitational contraction in reference to movement in the earth's crust; the extrusion of gases and vapors from the earth's interior, and the resultant changes in progress in the volume and composition of the atmosphere and hydrosphere. In these and still other fundamental conceptions of the primary causes of many of the changes in progress on the earth's surface the planetesimal hypothesis seemingly furnishes the cornerstone of a broader physiography than has as yet been framed.

IDEAL PHYSIOGRAPHIC TYPES.

During the descriptive stage of the study of biology the relationships among plants and animals were the chief end in view, and as a result of the conditions confronted, a systematic classification of animate forms under species, genera, families, etc., was formulated, which has been of infinite assistance during the more philosophical investigations that followed. Biological classification was facilitated, as learned later, by the fact that with the evolution of species there was concurrent extinction of species. As the tree of life grew, its branches became more and more widely separated.

Throughout the many changes the surface features of the earth have experienced there has also been development, not of the same grade, but analagous to that recognized in the realm of life; but the process of extinction has been far less complete than in the organic kingdom, and the connecting links between the various groups of topographic and other physiographic forms produced have persisted, and to a conspicuous extent still exist. The task of arranging the infinitely varied features of the earth's surface in orderly sequence, or systematic physiography, is thus far more difficult than the similar task which the flora and fauna of the earth present.

The utility of classification is fully recognized by physiographers, and various attempts have been made from time to time to meet the demand, but thus far without producing a generally acceptable result. Remembering that a scheme of classification of topographic and related forms is to be considered as a means for attaining a higher end, namely, the history of the evolution of the surface features of the earth, and should be of the nature of a table of contents to a systematically written treatise, the task of preparing such an index

becomes of fundamental importance to the physiographer. Since extinction of species among physiographic features has probably not occurred, and connected series of forms which grade one into another confront us, the practical lesson taught by the success of schemes of biological classification seems to be that ideal physiographic types should be chosen correlative with species among plants and animals.

By "ideal physiographic types" is meant complete synthetic examples of topographic and other physiographic forms, which will serve the rôle of well-defined species in the study of the surface features of the earth. Ideal types may be likened to composite photographs. They should combine critical studies of many actual forms, within a chosen range, and in addition be ideally perfect representatives of the results reached by specific agencies operating under the most favorable conditions. Like the idealized personalities of history and religions, the types of physiographic forms might well be more perfect than any actual example. When such idealized types shall have been chosen after careful study, described with care, and illustrated by means of diagrams, maps, pictures, models, etc., a comparison with them of actual examples on any portion of the earth for the purpose of identification and classification would be practicable. A well-arranged catalogue of ideal types would be an analytical table of contents to the history of the evolution of the features of the earth's surface, and constitute a scheme of physiographic classification.

In illustration of what is meant by an idealized physiographic type: We find in nature a great variety of alluvial deposits, now designated as alluvial cones or alluvial fans. They present a wide range and infinite gradations in size, shape, composition, structure, angle of slope, degree of completeness, stage of growth or decadence, etc. Complications also arise because of the association and intergrowth of such alluvial deposits with other topographic forms. In constructing the ideal type the characteristics of many of the most perfect actual alluvial cones, aided by a study of the essential features of similar artificial structures, should be combined in an ideally perfect and representative example which would serve as the type of its specie. All actual examples might be compared with such a type, their specific and generic relations determined, and their individual variations noted. In like manner, other topographic forms, ranging

from the more concrete species—such as constructional plains, cinder cones, sea cliffs, river terraces, etc.—to the more complex forms—as, for example, mountain ranges, mountain systems, and yet larger earth-features—could be represented by ideally perfect examples free from accidental and secondary complexities and accessories.

While individual examples of idealized topographic and other features of the earth's surface would serve as species, their arrangement under genera, families, etc., offers another problem, in which relationship or genesis should be the controlling idea.

The selection of idealized physiographic types, as just suggested, has for its chief purpose the reduction of endless complexities and intergradations to practicable limits. It is a method of artificial selection so governed that, while no link in the chain of evolution need be lost to view, certain links are chosen to represent their nearest of kin and serve as types. A danger to be marked by a conspicuous signal, in case this plan for aiding physiographic study is put in practice, is that it may tend toward empty ritualism. To give the idealized types chosen for convenience of classification an appropriate atmosphere, the fact that changes are constantly in progress—that mountains come and go even as the clouds of the air form and reform—should be ever present in the mind.

The process of evolution without concurrent extinction which characterizes the development of physiographic features finds expression also in related departments of nature, as, for example, in petrography, where, as is well known, it has greatly delayed the framing of a serviceable and logical system of classification. Indeed, the principle referred to may be said to be one of the chief distinctions between the organic and the inorganic kingdoms of nature.

THE PRIMARY FEATURES OF THE EARTH'S SURFACE.

The primary features of the earth's surface may consistently be defined as those resulting from the growth and internal changes of the lithosphere, while the modifications of relief resulting from the action of agencies which derive their energy from without the earth may be termed secondary features. The primary or major characteristics of the earth's surface, so far as now known, may be ranked in three groups, in accord with the agency by which they were principally

produced; namely, diastrophic, plutonic, and volcanic physiographic features. Each of the groups presents many as yet unsolved problems.

Diastrophic features.—Under this perhaps unwelcome term are included a large class of elevations, depressions, corrugations, faults, etc., in the surface portion of the lithosphere due to movements within its mass. The causes of the changes which produced these results are as yet obscure, and, although a fruitful source of more or less romantic hypotheses, may in general terms be referred to the effects of the cooling and consequent shrinking of a heated globe, or, under the terms of the planetesimal hypothesis, reckoned in part among the results of gravitational condensation. However obscure the fundamental cause, the results in view are real, and among the larger of the earth's features with which the physiographer deals. They are the greater of the quarry blocks, so to speak, which have been wrought by denuding agencies into an infinite variety of sculptured forms. Included in the list, as the evidence in hand seems to indicate, are continental platforms, oceanic basins, corrugated and block mountains, and many less mighty elements in the marvelously varied surface of the lithosphere. Not only the study of the shapes of these features of the earth's surface, but the movements they are still experiencing, and their transformations through the action of denuding agencies, claim the attention of the physiographer. While it may be said that the investigation of the method by which the primary relief of the lithosphere have been produced, falls to the lot of the geologist or the geophysicist, the physiographer is also interested in the many profound problems involved. The geologist and physiographer here find a common field for exploration, and can mutually assist each other. The task of the physiographer is to describe and classify the elements in the relief of the lithosphere due to diastrophic agencies, discriminate them from deformations due to other causes, and restore so far as practicable the forms that have been defaced by erosion. He can in this way assist the geologist by presenting him with the results of diastrophism free from accessories. With pure examples of the forms produced, the geologist will be better able to discover the causes and their mode of action, which have produced the observed results.

Although much has been accomplished in the way of determining which elements in the relief of the lithosphere are due to diastrophic

agencies, only a small part of the difficulties to be overcome have been met. The aim in view is the attaining of a knowledge of what would have been the shape and surface features of the solid earth, had there been no modifications by internal causes except diastrophism, and no changes in relief by erosion or other surface agencies. Included in this branch of physiography is the shape of the earth itself, in the study of which the physiographer became a geodesist. The earth's shape, and its primary surface features due to diastrophism, form the logical basis for physiographic study, in which ideal types of topographic forms declare their usefulness. In the geographical museums of the future, at the head of the long series of models of physiographic types illustrating the species, genera, families, etc., of the earth's surface features, should be placed ideal examples of the most typical elements of relief due to diastrophism.

Physiographers cannot rest content with the study of the shape of the lithosphere and of its surface relief, in which so much of the history of the earth is recorded, and refrain from searching for the deeper meanings these facts suggest, but must have freedom to invade the province of the geologist, the astronomer, the physicist, the chemist, and other subdivisions of the science of the cosmos, in search of truths bearing on his special line of work. This is particularly true in connection with the special department of physiography in hand, in which many of the branches of the river of knowledge have their sources.

Plutonic features.—Intimately associated with the irregularities of the earth's surface due to a decrease in its volume, and, as our reasoning tells us, dependent primarily on the same cause and at present only partially differentiated from them, are surface elevations and depressions, produced by the migration of portions of the earth's central magma from the deep interior toward or to the surface. A convenient but arbitrary subdivision of the matter forced outward from the earth's interior is in vogue among geologists, and rocks of plutonic and of volcanic origin are recognized. To the physiographer the distinction referred to is more suggestive than it appears from the point of view of the geologist, since the recognition of differences between topographic forms produced by the injection of fluid or plastic magmas into the cooled, rigid outer portion of the earth, and

topographic forms resulting from the extrusion of similar matter at the surface, is of genetic significance.

The simile was used above between the quarry blocks taken to the studio of the sculptor and the portions of the earth's surface brought by diastrophic movements within the sphere of influence of denuding agencies. There are two other primary classes of physiographic quarry blocks; one produced by intrusions of highly heated plastic or fluid magmas into the earth's crust, which cause upheavals of the surface above them, and the other due to extrusions of similar material at the surface, as during volcanic eruptions. The first of these two series of earth-features has received much less attention from physiographers than the second series.

Surface elevations due to local intrusions are well illustrated by the reconstructed forms of the Henry Mountains and the similar information in hand concerning several other regions. The topographic forms referred to have a conspicuous vertical measure in comparison with their breadth of base, and their prominence gained for them earlier recognition than in the case of related, and in part far more important, plutonic changes. It is to be remembered, however, that every intrusion of a magma into the earth's crust is, theoretically at least, accompanied by a change in the relief of the surface above. What surface changes accompany the lateral movements in the rocks invaded by a dike has eluded search and seemingly escaped conjecture. The surface changes produced by an extensive horizontal injection of a magma, as when intruded sheets are found in stratified terranes, is a matter of inference rather than of observation. Intrusive sheets are numerous, and the surface changes in topography, and consequently of drainage, that accompanied their production must have been important, but definite examples are wanting. Critical studies are needed in this connection, both by physiographers and by geologists, in order that the widely extended movements which have been observed in the surface of the lithosphere may be referred to their proper cause. How do we know, for example, that the many recorded changes in the relation of the land to sea-level may not in part be due to the injection of magmas into the earth's crust, instead of diastrophic movements as commonly supposed. The activity of volcanoes at the present day is warrant for the hypothesis that the concurrent process of sub-

surface injection is still in progress, and is today producing changes in the geography of the earth's surface.

Of still more importance to the physiographer than the surface changes known, or legitimately inferred, to have resulted from the formation of dikes, laccoliths, and intruded sheets are the elevations and possibly concurrent depressions of the surface of the lithosphere caused by still greater migrations of portions of the earth's central magma outward and into or beneath the rigid surface rind. Concerning these *regional intrusions*, as they may be termed, the geologist has furnished suggestive information. We are told, for example, that the granitic rocks from which the visible portion of the Bitter Root Mountains in Idaho have been sculptured are intrusive. The now deeply dissected granitic core of this mountain range measures not less than three hundred miles in length and from fifty to over one hundred miles in width. The area occupied by intrusive granitic rocks in the Sierra Nevada is seemingly still greater than in the case just cited, and other regional intrusions of even mightier dimensions are known in the vast region of crystalline rocks in Canada and elsewhere. The covers of sedimentary or other material which formerly roofed these vast intrusions in the instances now open for study have for the most part been removed by denudation, although instructive remnants of metamorphosed terrancs occurring as inliers in the granitic areas sometimes persist and reveal something of the nature of original domes of which they formed a part.

The surface changes in relief produced by the migration of magmas measuring thousands, and in many instances, as we seem justified in concluding, tens of thousands, of cubic miles, from deep within the earth outward, but failing to reach the surface, must be reckoned as of major physiographic importance. The very magnitude of the features of the earth's surface due to such intrusions has served to conceal their significance. We look in vain in our treatises on physiography for so much as a mention of them. Perhaps the excuse will be offered that the modifications in relief referred to are commonly grouped with the results produced by diastrophic agencies; but, if so considered, a differentiation seems necessary, and the significance of the topographic forms resulting from intrusions of various kinds clearly recognized.

In our dreamed-of museum of ideal physiographic types, mighty domes raised by regional intrusions, broad uplifts with perhaps sharply defined boundaries, elevated by relatively thin intruded sheets, as well as steep-sided domes with relatively small bases, concealing laccoliths, and the still smaller covers arching over plutonic plugs, will demand a place in the group of type examples of primary unsculptured elements in the relief of the lithosphere.

Volcanic features.—Elevations on the surface of the lithosphere due to the presence of material extruded from volcanic vents have long been recognized, but the specific, or, as perhaps may be consistently claimed, generic, differences among them has only recently claimed attention. Of primary importance in the classification of topographic forms of volcanic origin is the fact that volcanoes are both constructive and destructive in their action. Among the results of constructive action are included the changes produced by effusive, fragmental-solid, and massive-solid eruptions, each of which has furnished a wide range of primary topographic forms. The catalogue of recognized types includes lava plains and plateaus, cinder and lapilli cones, lava cones and domes, lapilli and dust plains, together with many minor structures, such as "spatter cones," "lava deltas," "lava gutters," "lava levees," and the various surface details of lava streams due to the flow of still mobile magmas beneath a stiffened crust which ranged in physical consistency from a highly plastic to a rigid and brittle condition. With these more familiar forms are to be included also the results of massive-solid extrusions, of which the "obelisks" of Mont Pelé are the most striking examples.

Our present list of destructional topographic forms due to volcanic eruptions includes decapitated cinder, lapilli and lava cones, and subsided and broken lava domes, calderas, crater rings, etc., together with cones of various kinds breached by outflowing lavas; and, as minor features, the floated blocks sometimes carried on lava streams, or the *moraines of lava flows*, as they may suggestively be termed, the subsided and broken roofs of lava tunnels, etc.

The interesting contributions made during the past decade to the list of topographic forms resulting from the action of volcanic agencies are highly suggestive, and warrant the belief that still more numerous and equally important results in the same direction will reward more

extended and more careful search. The progress of physiography would evidently be accelerated by a systematic review and a more definite classification of the topographic forms, both constructional and destructional, known to have resulted from volcanic agencies, and a more critical selection of types to serve as species than has as yet been attempted. From such a catalogue something of the underlying principles governing the many ways in which the relief of the earth's surface has been modified, and is still being changed through the agency of volcanoes, would make themselves manifest, and predictions rendered possible which would facilitate further study. The analogy between lava streams and rivers, on the one hand, and glaciers, on the other, suggests interesting and instructive methods for considering the entire question of the movements of liquids and solids on the earth's surface.

While the topographic changes produced by volcanic agencies are of chief interest to the physiographer, they lead him to profound speculations in reference to the nature of the forces to which they are due, the source and previous condition of the matter extruded during eruptions, and the study of the existing relations between the earth's interior and its surface. The great, and as yet but partially answered, questions: Whence the heat manifest during volcanic eruptions? What is the source of the energy which forces lava to rise from deep within the earth through volcanic conduits to where it is added to the surface, perhaps ten to twenty thousand feet above sea-level? and, what is the source or sources of the steam discharged in such vast quantities during eruptions of even minor intensity? are as of great interest to the physiographer as they are to the geologist, and furnish another illustration of the unity of nature-study. From the new point of view furnished by the author of the planetesimal hypothesis, the many questions the physiographer is asking concerning volcanoes and fissure eruptions are rendered still more numerous by the suggestion that these fiery fountains are the sources from which the ocean and all the surface waters of the earth have been supplied. This startling revelation, as it seems, makes a still more urgent demand than had previously been felt for quantitative measures of the vapor discharged from volcanic vents. Nor is this all; with the steam of volcanoes is mingled various gases, and the mode of origin of the

earth's atmosphere as well as the changes it is now undergoing, is a theme in which the physiographer is profoundly interested.

Volcanic mountains are numbered among the most awe-inspiring of topographic forms; the solid additions which volcanoes make to the surface of the lithosphere are in view, and the contributions to the atmosphere of vapors and gases from the same sources are tangible facts; but another phase of the great problem is also of interest to the physiographer, namely, what changes take place in the rigid outer shell of the earth by reason of the transfer of such vast volumes of material as are known to have occurred from deep within the earth to its surface. The magmas which have been caused to migrate and come to rest for a time, either as intrusions within the earth's outer shell, or as extrusions on its surface, are measurable in millions of cubic miles. In connection with the profound questions concerning the formation of folds and fractures in the earth's crust, an agency is thus suggested comparable in importance with loss of heat, as under the nebular hypothesis, or with gravitational compression, as explained by the planetesimal hypothesis. In the many discussions that have appeared as to the adequacy of earth contraction to account for the origin of mountains of the Appalachian type, I have been able to find but one mention of the rôle played by the transfer of matter from deep within the earth outward, and in part its extrusion at the surface, in causing folds in the crust from beneath which it was derived. Problems of fundamental importance are outlined by the considerations under review.

To the immediate question, What is the best plan for enlarging our knowledge of the physiography of volcanoes? the reply seems pertinent: Press on with the study of both active and dormant or extinct examples. In this connection it should be remembered that, while the individual volcanoes and volcanic mountains which have been critically studied can be enumerated on the fingers of one's hands, those which are practically unknown number many thousands. The fact that Mont Pelé and La Soufrière of St. Vincent during their recent periods of activity furnished examples of at least two important phases of volcanic eruptions not previously recognized is an assurance of rich returns when other eruptions are critically investigated.

While it is difficult to formulate the precise questions so numerous

are they, to be asked of volcanoes, whether active, dormant, or dead, and in various stages of decay and dissolution, it is plain that all the facts that can be learned concerning them should be classified and put on record, and their more obvious bearings on the fundamental questions concerning the condition of the earth's interior, and the changes there taking place, pointed out. In this connection—and as is true in all branches of research—the fact may be recalled that energy expended in discovering, classifying, and recording facts decreases the time and force necessary for the framing of multiple hypotheses. With an abundance of well-classified and pertinent observations in hand, the nature of the thread on which the gems of truth should be strung usually declares itself.

Résumé.—On a previous page of this essay the desirability was suggested of recognizing ideal types with the aid of which the multitudinous surface features of the earth could be classified and studied. Thus far we have considered the elements in the relief of the earth's surface which have resulted from changes within its mass. We term them primary physiographic features, because their birth precedes the modifications of the lithosphere due to agencies acting externally. They are (1) the topographic forms resulting from contraction on account of cooling, or of condensation owing to growth in mass; (2) the surface changes produced by intrusions of magmas into the earth's outer shell; and (3) the results of volcanic eruption. Among the more important idealized models in our future physiographic museum there should be displayed continental platforms, oceanic basins, corrugated mountains, block mountains, domes of various and some of vast dimensions upraised by intrusions, volcanic cones, lava plateaus, etc. These are the major physiographic types, or the larger monoliths from which the rock-hewn temples of the earth have been sculptured by forces acting on the surface of the lithosphere and deriving their energy mainly from the sun. Resulting from surface changes come a vast array of both constructive and destructive physiographic features, which may consistently be termed secondary. Under secondary features may be included also relational topographic forms, such as islands in water, in glaciers, and in lava fields. In the study of the primary features of the earth's surface the work of the physiographer is most intimately linked with that of the geolo-

gist, but, on passing to the secondary feature, the influence of life becomes apparent, and the relation of man to nature is in the end the leading theme.

SECONDARY PHYSIOGRAPHIC FEATURES.

The most familiar features of land areas, as is well known, are those which owe their existence to the work of moving agencies resident on the earth's surface, such as the wind, streams, glaciers, waves, currents, etc. The forces at work are set in motion by energy derived from without the earth, and the material worked upon is brought within the range of their activities by forces resident within the earth which cause deformations of, or additions to, its surface. The earth-born primary physiographic features are thus modified by sun-derived forces, and a vast array of secondary modifications of relief are produced which give variety and beauty, particularly to those portions of the lithosphere which are exposed for a time to the air. The study of secondary physiographic features has produced a rich and abundant harvest, especially during the last quarter of a century, and the returns are still coming in with seemingly an accelerated rate.

The themes for study are here mainly the various processes of erosion and deposition of the material forming the outer film of the lithosphere, and the characteristics of the destructive and constructive topographic forms produced. With the knowledge gained concerning the changes now in progress on the ocean's shore, in the forest, by the river side, on the snow-clad and glacier-covered mountains, etc., the physiographer seeks to decipher the records made in similar situations during the past. Two groups of problems are in sight in this connection; one is concerned with observing, classifying, and recording the changes now in progress; and the other has for its chief aim the translation, in terms of the agencies now at work, of the records left by past changes. We find that today the same area is being inscribed perhaps in several different ways. The surface of the earth, like an ancient manuscript, is frequently written upon in different directions, and with different characters. It is the duty of the physiographer to translate this ancient palimpsest, and deduce from it the history of the development of the features of the earth's surface. It has

been said that "geology is the geography of the past," but to the physiographer this formula has a yet deeper meaning. There is a physiography of the past, of venerable antiquity, which has begun to receive attention. Ancient land surfaces, buried during geological eras beneath terranes which were deposited upon them, have here and there been exposed once more to the light of the sun, owing to the removal by erosion of their protecting coverings. In northern Michigan, for example, one may gaze on the veritable hills and valleys which were fashioned by the wind, rain, and streams of pre-Potsdam days of sunshine and shower. These *fossil landscapes* invite special study, not only on account of their poetic suggestiveness, but as furnishing evidence, supplementary to that afforded by organic records, ripple marks, shrinkage cracks, etc., as to the oneness of nature's processes throughout eons of time. The consideration of past physiographic conditions, the tracing of former geographic cycles, the study of the concurrent development of primary and secondary physiographic features, the causes and effects of past climatic changes, and the influences of these and still other events of former ages on the present expression of the face of nature, offer not only a fascinating, but a far extended field for research.

One especially important development of the study of past physiographic conditions, and the manner in which they merge with the present phase of the same history, is the connection between the life of the earth and its control by physical environment. The present and past distribution of floras and faunas affords important data supplementary to those recorded by abandoned stream channels, glacier scorings, elevated and depressed shore lines, desiccated lake basins, and other physical evidences of former geographic changes.

In the excursions into the domain of the unknown, here suggested, the physiographer seeks the companionship and counsel of both the geologist and the biologist.

PHYSIOGRAPHY AND LIFE.

In the study of the relation between physiography and the present state of development of living organisms on the earth, it is convenient and logical to recognize two great subdivisions: the one, the control exerted by physiographic features on the distribution of plants and

animals; and the other, the reaction of life on its physical environment, and the modification in the relief of the lithosphere and the geography of its surface thus produced. Although man is embraced in each of these categories, there are sufficient reasons for considering his relations to his environment separately from those of the lower forms of life.

The dependence of life on its physical environment has received much attention from botanists and zoölogists, and is perhaps the leading thesis now claiming their attention. So important is this branch of study that a name "ecology," has been coined by which to designate it. The phase of nature-study thus made prominent pertains to the marvelously delicate adjustment that has been found to exist between the distribution of life and the nature of the region it inhabits. Among the interesting themes involved are topographic relief, degree of comminution and disintegration of the surface blanket of rock waste, depth and freedom of penetration of water and air into the life-sustaining film of the earth's surface, and the concurrent changes in life with variations in these and other physical conditions. In this most fascinating branch of study the ecologist borrows freely of the physiographer, and makes payment in peat bogs, living vegetable dams in streams, organic acids serviceable for rock disintegration and decay, deposits of calcium carbonate and silica in lakes and about springs, vast incipient coal beds in the tundras of the far north, and numerous other ways.

From the physiographic point of view, however, the many and intricate ways in which life leads to modifications in the features of the lithosphere are of more direct interest than studies in ecology. Much has been accomplished in this direction, but it is evident that as yet but partially explored paths leading through the borderland between biology and physiography remain to be critically examined.

In connection with the changes in progress on the earth's surface, due to the influence of organic agencies, and the application of that knowledge in interpreting past changes, the study of the influences exerted by the lowest forms of life in both the botanical and the zoölogical scale seems most promising to the physiographer.

The secretion of calcium carbonate and silica by one-celled organisms, as is well known, has led to the accumulation of vast

deposits like the oozes on the sea-floor, beds of diatomaceous earth, deposits about hot springs, the so-called marl of fresh-water lakes, etc. A review of the several ways in which such accumulations are formed, and an extension of the search in various directions, give promise that other and equally wonderful results flowing from the activities of the lowest form of life would be discovered. The mode of deposition of iron, and perhaps of manganese, the generation of hydrocarbons, the origin of extensive sheets of seemingly non-fossiliferous limestone and dolomite, the method by which the beautiful onyx marbles are laid down, film on film, the nature of the chert so abundant in many terranes and so conspicuous in the surface waste of extensive regions, and other equally important deposits which exert a profound and frequently controlling influence on topographic forms, seemingly demand study with the hypothesis in mind that they owe their origin to the vital action of low forms of plants or animals. Not only the concentration of mineral matter by one-celled organisms, but the part played by similar organisms in the comprehensive processes of denudation, also invites renewed attention. Many of the organisms in question do not secrete hard parts, and hence are incapable of directly aiding in the concentration of inorganic solids on the surface of the lithosphere. If not assisting in the building of physiographic structures, the suspicion is warrantable that they are engaged in sapping their foundations. The wide distribution of one-celled organisms—and indeed, as one may say, their omnipresence on the earth's surface—and their seeming independence, as a class, to differences in temperature, light, and humidity, enable them to exert an unseen and silent influence, not suspected until some cumulative and conspicuous result is reached. The importance of bacteria in promoting decay, and in consequence the formation of acids which take a leading part in the solution and redeposition of mineral substances, the rôle played by certain legions of the invisible hosts in secreting nitrogen from the air and thus aiding vegetable growth and perhaps to be held accountable also for the concentration of nitrates in cavern earths, the part others play in fermentation, and the diseases produced in plants and animals by both bacteria and protozoa, render it evident that an energy of primary importance to the physiographer is furnished by these the lowest of living forms.

Physiographers were given a new point of view when Darwin explained the part played by the humble earthworms in modifying the earth's surface. As it seems, still other advances in our knowledge of the changes in progress in the vast laboratory in which we live may be gained by studying the ways in which organisms far lower in the scale than the earthworm are supplying material for the building of mountains or assisting in the leveling of plains.

In brief, a review of the inter-relations of physiography and life, shows that from the lofty snow-fields reddened by *Protoccocus*, to the bottom of the ocean, the surface of the lithosphere is nearly everywhere enveloped in a film teeming with life. In part the vital forces at work are reconcentrating material and adding to the solid framework of the globe, and in part, but less obviously, aiding in rock decay and disintegration. Throughout this vast complex cycle of changes new physiographic features are appearing, others disappearing, and one and all, to a greater or less degree, are undergoing modifications. The wide extent of the changes in progress, and their known importance in certain instances, are justification for the belief that the physiographer as well as the ecologist will find many problems of fundamental importance to his science in the inter-relations of life and physiographic conditions.

PHYSIOGRAPHY AND MAN.

Go forth, subdue and replenish the earth, is the language of Scripture. The observed results show that, while man strives to bend nature to his will, he himself is a plastic organism that is molded by the many and complex external forces with which it comes in contact. Here again two groups of themes present themselves to the physiographer: one, embracing the influences of environment on man; and the other, the changes in the features of the earth's surface, brought about by human agencies. In the first the physiographer can aid the anthropologist, the historian, the socialist, etc.; and in the second, which is more definitely a part of his own specialty, he searches for suggestive facts throughout the entire domain of human activities. It is in these two directions that the student of the earth's surface finds the most difficult and the most instructive of the problems in which he takes delight, and the richest rewards for his efforts.

The control exerted by physiographical environment on human development is so subtle, so concealed beneath seemingly accidental circumstances, and its importance so obscured by psychological conditions, that its recognition has been of slow growth. The countless adjustments of both the individual man and of groups of men in communities, nations, and races to physical conditions, is so familiar that the sequence of causes leading to observed results passes as a matter of course and to a great extent fails to excite comment. The due recognition of the influence of physiographic environment on history is now coming to the front, and, as is evident, the rewriting of history, and especially the history of industry, from the point of view of the physiographer, is one of the great tasks of the future. The problems in this broad field are countless, and the end in view is similar to those embraced in dynamical physiography, namely, the study of the various ways in which man is now influenced by his physical environment, with the view of interpreting the records of similar changes in the past and of predicting future results. Or more definitely formulated: peoples have reached a high degree of culture under certain multiple conditions of environment, while other peoples, exposed to other combinations of conditions, have remained stationary, or retrograded and become degenerate. What are the essential conditions in control in the one case or the other? Can predictions be made as to what the results of a given combination of physical conditions on a given community will be, in spite of that other and still more mobile, and as yet but little understood, group of conditions embraced under the term *psychology?* Many profound questions, in the solution of which the physiographer unites his efforts with those of the student of the humanities, present themselves for study during the century that is yet young.

Within the broader questions just suggested are many others that are more concrete and definite, and of vital importance to mankind, which can be conveniently grouped under the term *economic physiography.* The problems which here present themselves share their chief interests with the engineer. They relate to plans for transportation in all of its various forms, drainage, irrigation, water supply, sanitation, choice of municipal locations, control of river floods, selection of cities for homes, farms, vineyards, factories, etc. In

every branch of industry a critical knowledge of the physical conditions, both favorable and adverse to the economic ends in view, and of the limitations of the daily, seasonal, and secular changes they experience, is of primary commercial importance. Although the money value of truth should be a secondary consideration to the truth-seekers, a critical study of the influence of environment on industry is as truly a matter of scientific research as any of the less complex and less directly utilitarian branches of physiography.

The reaction of human activities on physiographic features presents two great groups of problems. These embrace, on the one hand, the far-reaching and frequently cumulative effects of man's interference with the delicate adjustment reached in natural conditions before his influence became manifest; and, on the other hand, the effects of such changes on man's welfare.

A change amounting to but little less than a revolution in the long-established processes by which the features of the earth's surface are modified and developed, accompanied the advancement of man from a state of barbarism to one of civilization, and is most strikingly illustrated when men skilled in the arts migrate to a previously unoccupied region. This new factor in the earth's history demands conspicuous changes in the methods of study usually employed by physiographers, and makes prominent a series of investigations the full significance of which is as yet obscure. The wholesale destruction of forests, drainage of marshes, diversion of streams, building of restraining levees along river banks, tillage of land, abandonment of regions once under cultivation, the introduction of domestic animals in large numbers into arid regions and the consequent modification, and frequently the destruction, of the natural vegetal covering of the soil, and many other sweeping changes incident to man's industrial development, are fraught with consequences most significant to the student of nature, and of profound import to the future of the human race. From the point of view of the physiographer, the ultimate result of these great changes in the surface conditions of the earth can to a great extent be expressed in one word, and that word is *desolation*. In view of the suicidal lack of forethought manifest in the activities of peoples and, as experience shows, increasing in many directions in destructiveness with industrial prog-

ress, the problems that confront the physiographer are not only what far-reaching changes in the surface condition of the land result therefrom, but how the ruin wrought can be repaired, and how human advancement can be continued and its deleterious consequences on the fundamental conditions to which it owes its birth and development be avoided or lessened. Considerations which lessen the horrors of the regions crossed by industrial armies are that nature, no matter how severely torn, has great recuperative power and tends to heal her wounds; and also that man, through the science of agriculture particularly, although greatly modifying natural conditions, is able to reconstruct his environment and, so long as intelligent care is exercised, adjust it to his peculiar needs. In the relations of physiography to man, as the above hasty sketch is intended to show, the themes for research are many and important. As a suggestive summary, they include the review of history with the aid that modernized physical geography furnishes; the recognition of a strong undercurrent due to inorganic conditions in the political, social, and industrial development of peoples; the incorporation of physiographic laws into the formulas used by the engineer in all of his far-reaching plans; the calling of a halt in the wanton destruction of the beauties of nature, and the providing of a check on the greed of man which casts a baneful shadow on future generations. Great as are the results to be expected from a better knowledge of the mode of origin of the earth, its deformation by internal changes, and the removal and redeposition of material by forces resident on its surface, the combined results of all these studies culminate in the relation of man to his environment.

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